F I N A L R E P O R T

Risk Based Remediation Concentrations

Car Park Waste Encapsulation

Prepared for

Orica Australia Pty Ltd

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Glossary of Terms

Absorption - The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acceptable Daily Intake (ADI) - The amount of a chemical a person can be exposed to on a daily basis over an extended period of time (usually a lifetime) without suffering deleterious effects.

Acute exposure - Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect - A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect - A change in body function or cell structure that might lead to disease or health problems

Antagonistic effect - A biologic response to exposure to multiple substances that is **less** than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

ANZECC - Australia and New Zealand Environment and Conservation Council

Background level - An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation - Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Body burden - The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

Carcinogen - A substance that causes cancer.

Chemical of Potential Concern (COPCs) – Chemical present in environmental media at a concentration sufficiently high or there is a sufficiently high degree of uncertainty to warrant further assessment in relation to risks.

Chronic exposure - Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Dermal contact - Contact with (touching) the skin [see route of exposure].

Detection limit - The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Dose - The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Exposure - Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment - The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

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Exposure pathway - The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as chemical leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching); and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Groundwater - Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Guideline Value - Guideline value is a concentration in soil, sediment, water, biota, or air (established by relevant regulatory authorities, such as the DEC or institutions such as the NHMRC, ANZECC and WHO), that is used to identify conditions below which no adverse effects or nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter- and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines will have different names such as investigation level, trigger value, ambient guideline, etc.

Hazard Index and Hazard Quotient – Hazard quotient is the ratio of daily chemical calculated for a specific receptor and exposure pathway, to the acceptable or safe dose (ADI, TDI, RfD, etc.) for that chemical. A value less than 1 indicates that the intake is less than the safe intake. A hazard index is the sum of the hazard quotients for all exposure pathways for a receptor.

Ingestion - The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation - The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure - Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Lowest-observed-adverse-effect level (LOAEL) - The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

MRL – The Maximum Residue Limit (MRL) is the maximum residue concentration from the legal use of an agricultural or veterinary chemical that is recommended as the acceptable maximum concentration in a food.

Metabolism - The conversion or breakdown of a substance from one form to another by a living organism.

NHMRC - National Health and Medical Research Council.

No-observed-adverse-effect level (NOAEL) - The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

Plume - A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or the envelope of a contaminant moving with groundwater.

Point of exposure - The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population - A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Receptor population - People who could come into contact with hazardous substances [see exposure pathway].

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Reference dose (RfD) – Specifically refers to a toxicity value identified by the USEPA. The RfD is similar to an ADI or TDI and incorporates uncertainty or safety factors to identify a safe dose assuming daily lifetime exposure to a substance that is unlikely to cause harm in humans.

Reasonable Maximum Exposure (RME) - The RME represents an exposure scenario based on a set of exposure parameters that is representative of expected maximum exposure for that receptor and activity. The RME would not be expected to be exceeded except under highly specific and exceptional circumstances.

Reference concentration (RfC) - The concentration of a specific chemical in air to which a human population may be exposed to without appreciable risk to their health. RfC's are identified by the US EPA.

Risk - The probability that something will cause injury or harm.

Risk reduction - Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Route of exposure - The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Serious Risk Concentration (SRC) – SRCs are defined by the Dutch for human health and the environment on the basis of risk assessments relevant to the specific media. The SRCs are used in Dutch legislation to identify Intervention Values that trigger a requirement for remediation. SRCs represent concentrations where risk targets are exceeded for the specific receptor at a generic level (i.e. non site specific).

Surface water - Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Synergistic effect - A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Tolerable Concentration (TC) - A TC (established by WHO) is an airborne concentration to which it is believed that a person can be exposed continuously over a lifetime without deleterious effects. The TC is based on non-carcinogenic effects and is usually calculated by applying uncertainty factors to a NOAEL or LOAEL. As such, the TC is similar to the USEPA reference concentration for inhalation exposures and ADI, TDI or RfD for oral exposures.

Tolerable Daily Intake (TDI) - The term tolerable daily intake (TDI) is used by the International Program on Chemical Safety (IPCS) to describe exposure limits of toxic chemicals and the term acceptable daily intake (ADI) is used by the World Health Organization (WHO) and other national and international health authorities and institutes.

Toxicological profile - An assessment that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology - The study of the harmful effects of substances on humans or animals.

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Uncertainty factor - Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

WHO – World Health Organisation

Section 1 Introduction

1.1 General

URS Australia Pty Ltd (URS) has been engaged by Orica Australia Pty Ltd (Orica) to derive risk-based remediation concentrations for the Car Park Waste Encapsulation (CPWE), which is located at the north eastern corner of the Botany Industrial Park (BIP), New South Wales (NSW) (known as the CPWE site, refer to **Figure 1**).

The CPWE site is "L"-shaped, and contains approximately 45,000 m^3 of contaminated soil in an engineered cell encapsulated by a synthetic liner (Hypalon). The cell is capped with sand and a bitumen surface. Soil and other materials placed within the encapsulation originated from an open area where drummed chlorinated hydrocarbon (CHC) waste had been stored. The material included a wide range of chlorinated compounds including hexachlorobenzene (HCB), hexachloroethane (HCE), hexachlorobutadiene (HCBD), octachlorostyrene (OCS) and tetrachloroethene (PCE). In addition to these contaminants, other contaminants and debris were unearthed with the ash and transferred to the compound. Including approximately 590 m^3 of contaminated ash from another part of the BIP site, which had become impregnated with CHCs from the former Vinyls Plant.

Following a review of remediation options for the CPWE and extensive community consultation, it was decided that Directly-heated Thermal Desorption (DTD) technology was the most appropriate option. DTD technology has been used for over 20 years at many remediation sites, mainly in the USA, and including the Allied Feeds site at Rhodes Peninsula (currently, since May 2006, operated by Thiess)[1]

The CPWE material is to be excavated and treated in the DTD Plant. The remediated material would be used to reinstate the validated excavation at the CPWE area to the level of Corish Circle. Some surplus material would remain stockpiled on site for future reuse on other areas of the BIP. The aim of this report is to derive risk based concentrations that allow for this remediated material to be reused at the CPWE and other areas on site. The risk based concentrations will also be utilised to validate the un-remediated material *in situ* to enable determination of limits of excavation.

As part of the BIP, the CPWE site is zoned commercial/industrial. It is assumed that any area that Orica would wish to place remediated material would be zoned commercial/industrial. The risk based concentrations are only relevant to soil remaining within the BIP after treatment. The concentrations are not applicable to material that may be disposed off site. If material was to be disposed off site, it would need to be undertaken in accordance with NSW Department of Environment and Conservation (DEC) waste disposal concentrations.

1.2 Requirements for Remediation Criteria

The derivation of remediation criteria for the CPWE remediation project is part of the overall Environmental Assessment (EA), which has been prepared by HLA-Envirosciences Pty Ltd (HLA). The EA is to be conducted in accordance with the Director General's Environmental Assessments Requirements (EARs) issued on the 29 August 2006. More specifically, the Director General's Requirements have identified the following with respect to the remediation criteria:

The Environmental Assessment must clearly indicate the proposed remediation criteria to be applied to the site, including details of how these criteria have been derived. The Environmental Assessment must demonstrate how the treatment will achieve:

- *A statistical average dioxin, furan and dioxin-like PCB WHO-TWQ of less than 1 µg/kg (1000 ppt) determined with a methodology acceptable to the DEC;*
- *An aggregate concentration of scheduled chemical waste constituents of less than 2 mg/kg;*

[1] Further details on the remediation project currently being undertaken at Rhodes can be found at http://www.rhodesremediation.com.au/

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- *A polychlorinated biphenyl concentration of less than 2 mg/kg;*
- *The relevant requirements of the HCB Waste Management Plan 1996; and*
- *Best practice limits as demonstrated with the technology assessment application to the DEC for other principal contaminants of concern.*

Matters related to technology specific best practice criteria for treated material, which were raised in the Director General's EARs above, are discussed in the HLA (2007) Remedial Action Plan (RAP) and EA.

The overall objective of this assessment is:

- To develop risk-based remediation concentrations for the treated material to enable validation of the CPWE site after treatment has been completed. The risk-based remediation concentrations are developed for use within the BIP and as such are relevant to the existing industrial land use of the BIP. The risk based concentrations will also be used to validate the extent of remediation and material to remain *in situ*.

The risk-based remediation concentrations are not intended to be treatment goals for the waste but may be used for identifying on-site reuse options for the treated waste.

1.3 Approach

The approach taken to the development of the risk-based remediation concentrations is generally in accordance with the health risk assessment protocols/ guidelines recommended by enHealth (Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, June 2002). These guidelines draw on and are supplemented by those provided by Australian and New Zealand Environment and Conservation Council (ANZECC) and National Health and Medical Research Council (NHMRC) and detailed in the documents:

- "The Health Risk Assessment and Management of Contaminated Sites" (Contaminated Soil Monograph Series (CSMS) 1991, 1993, 1996 and 1998 and enHealth 2002b);
- ANZECC/NHMRC (1992) Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites; and
- The National Environmental Protection Measure (NEPM) (Schedule B(4), Guideline on Health Risk Assessment Methodology, 1999), prepared by the National Environmental Protection Council (NEPC).

ANZECC and NHMRC currently provide only general guidance and, as such, the more detailed protocols and guidelines developed by the United States Environmental Protection Agency (USEPA) (1989 and 2001) are referred to for supplementary guidance.

The derivation of remediation concentrations for the site-related chemicals at the Orica CPWE site has been based on assumptions relevant to potential for human exposure to the chemicals using guidance recommended and endorsed by Australian regulators in particular the DEC and NSW Health.

The derivation of the human health risk-based remediation concentrations is divided into the following four prime tasks:

- Issue Identification/Data Evaluation;
- Exposure Assessment;
- Toxicity/Hazard Assessment; and
- Risk Characterisation (setting remediation concentrations).

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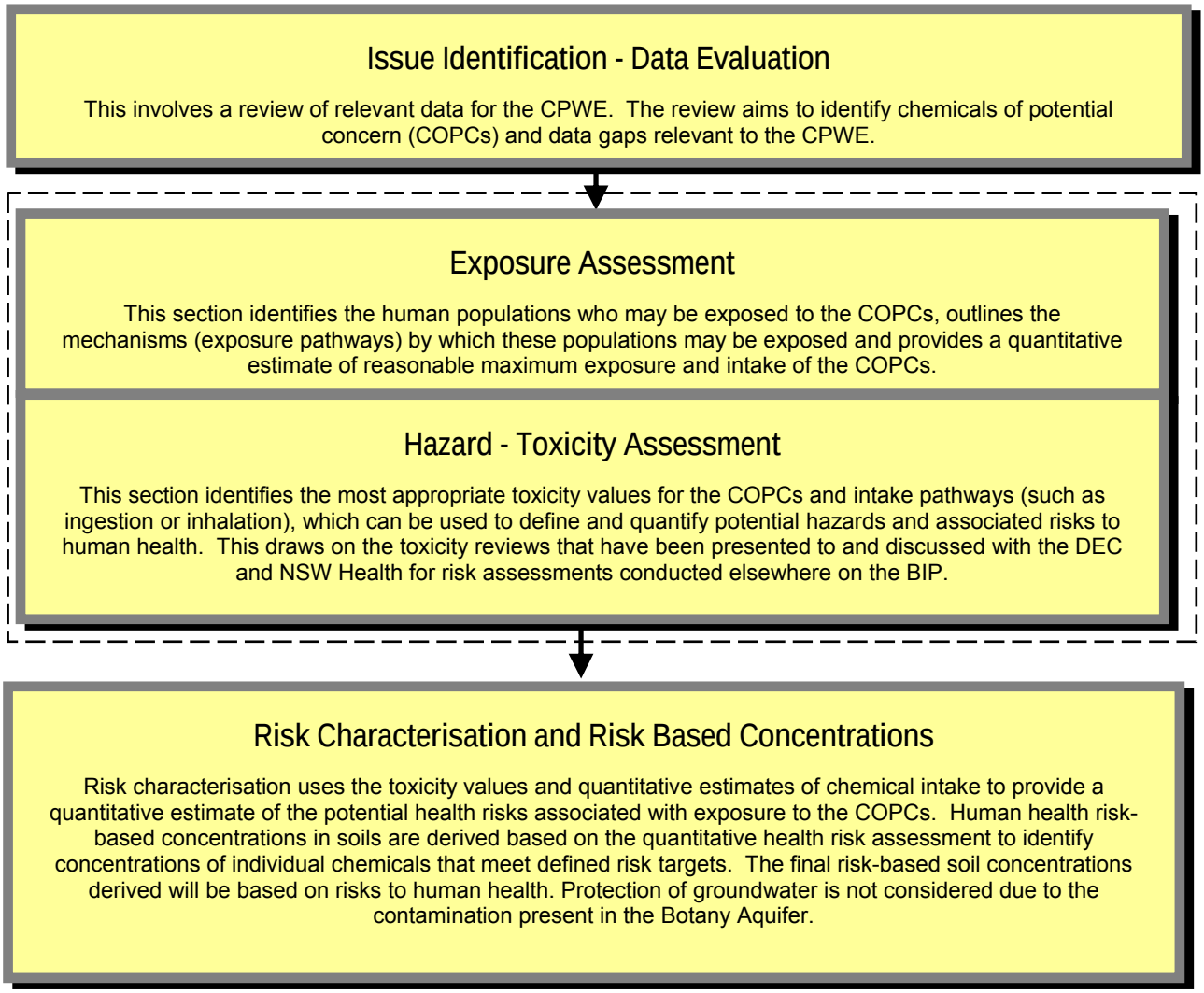
The following diagram illustrates the key tasks required in the assessment of risk to human health.



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1.4 Features of Risk-Based Remediation Concentrations

As stated, the derivation of risk-based remediation concentrations has been carried out in accordance with international best practice and general principles and methodology accepted in Australia by groups such as ANZECC, NHMRC, NEPC, and enHealth. However, there are certain features of the methodology that are fundamental to the assessment of the outputs. These are summarised below:

- The risk assessment is a mathematical procedure that addresses potential exposure pathways based on an understanding of the contaminants present in the CPWE site. The calculations are based on estimation of worst-case exposure and, hence, are expected to overestimate the actual risks.
- Conclusions can only be drawn with respect to the contaminated media associated with the CPWE site. This risk assessment develops remediation concentrations for retention on the BIP of the contaminated media after treatment at the CPWE site. The concentrations are not applicable to any other circumstance. Assessment of the risks from the remedial activities is addressed separately as part of the EA process.
- The calculations reflect the current state of knowledge regarding the potential health effects of COPCs identified at the CPWE site. This knowledge base may change as more insight into biological processes is gained, further studies are undertaken, and more detailed and critical review of information is conducted.

Section 2 Background

2.1 Previous Investigations

The calculation of risk-based soil remediation concentrations has been prepared using data and assessments from the following sources which provide a description of the waste contained within the CPWE.

- HCB Waste Management Plan Waste Material Characterisation (Car Park Waste). Prepared by AGC Woodward-Clyde Pty Ltd (Woodward-Clyde, now known as URS), 9 February 1998.

  Woodward-Clyde (1998) characterised the waste material in the encapsulation by the collection of soil gas samples from three cores to a depth of 3.9 m, and 41 samples of waste material collected from three locations within the CPWE.

- Final Report Car Park Waste Encapsulation and Denison Street Stockpile - Further Characterisation. Prepared by URS, 2 March 2007.

  URS (2007) conducted an intrusive investigation and factual report at the CPWE and the Denison Street Stockpile. Site works were conducted in August 2006 and chemical and physical analysis conducted between August and December 2006. 10 soil sample locations were drilled and fill samples were collected at 0 m, 1 m, 2 m, 3 m, 4 m and 5 m below the upper Hypalon liner. Sampling of the soil/fill beneath the base of the encapsulation was also undertaken, by drilling at an angle of 45 degrees to a depth of approximately 4 to 5 m below ground level, at two locations.

It is noted that a number of other reports are available for the CPWE site; however, these do not provide any more comprehensive characterisation of waste within the CPWE and many are not relevant to the derivation of soil remediation concentrations and are not considered further in this report.

The following presents a summary of key aspects of these reports relevant to the identification of COPCs.

2.2 Description of Site and Surrounding Areas

2.2.1 Site Location and Description

The BIP is located on the northern side of Botany Bay approximately 11 km south of the Sydney Central Business District (CBD). The BIP occupies approximately 74 ha.

The BIP site is an operating industrial site and as such the on site environment is limited to grassed and small garden areas within the industrial site and landscaping along the boundary with Denison Street.

The CPWE was constructed in 1980 adjacent to the Olefines II Administration building. The CPWE site is "L" shaped, lined with a synthetic liner (Hypalon) – an engineered cell in the north east corner of the BIP (refer to **Figure 1**). The cell is capped with sand and a bitumen surface which was utilised as a car park and is currently used for driveway access to the Olefines car park which is adjacent to the western boundary of the CPWE. The encapsulation consists of approximately 45,000 m^3 of soil (sand/ash/peat) contaminated with a range of CHCs including HCBD, HCE, OCS, HCB and PCE.

Soil and other materials, which were placed within the encapsulation, originated from an open area where drummed CHC waste had been stored in the past. Details on the construction of the encapsulation are presented in the Waste Material Characterisation Report (Woodward-Clyde 1998) and the Car Park Waste Encapsulation and Denison Street Stockpile - Further Characterisation Report (URS 2007).

Section 2 Background

The remediation works proposed for the CPWE will take place in two main locations on the BIP (refer to the RAP (HLA 2007) and EA for more detail):

- The CPWE area (owned by Orica). An Excavation Soil Building (ESB) will be constructed to enclose the excavation area and excavation of the contaminated soil will take place within this building.
- The former Propathene Plant area (owned by Orica). The soil pre-treatment and remediation (DTD) process will be located in the former Propathene Plant area within the BIP, south west of the CPWE area. The Propathene Plant has been previously demolished and the area is effectively clear. A Feed Soil Building (FSB) will be constructed where all soil preparation activities will take place. The DTD Plant will also be constructed in this area.

Transport of excavated material from the ESB to the FSB will be undertaken by covered truck on internal BIP roads.

The BIP is currently zoned Industrial 4(a) under the City of Botany Bay Local Environmental Plan. It should be noted that the description for this zoning includes child care centres, community facilities and motels. Based on the nature of the industry currently (and expected to be) located within the BIP, it is expected that use of the BIP will be in keeping with existing heavy industrial uses that do not include community centres, childcare facilities or motels. Hence, for the purposes of this risk assessment these more sensitive land uses have not been considered.

2.3 Surrounding Land Uses

The current land uses, based on council zoning, in the immediate vicinity of the BIP and CPWE are shown on **Figure 1** and the aerial photograph (**Figure 2**). The following land uses occur within a distance of 2 km of the BIP:

- Residential;
- School;
- Commercial (including offices and shops);
- Industrial (including food processing);
- Recreational (golf courses, playing fields, Penrhyn Estuary and Botany Bay); and
- Public open space.

More specifically, land use in the area adjacent to the CPWE includes the following:

Direction from CPWE	Description and Land-Use
North	Commercial properties are located adjacent to the northern boundary of the CPWE/BIP site. It is noted that commercial/industrial buildings have been constructed on land immediately adjacent to the CPWE.
East	Corish Circle is located adjacent to the eastern side of the CPWE/BIP site. The Hensley Athletics Field (recreational area) is located across Corish Circle with residential properties located further east across Denison Street.
South	The BIP extends to the south of the CPWE with the former Propathene Administration building, Gate 4 and Olefines Administration building located closest to the CPWE.
West	The BIP extends to the west of the CPWE with the Olefines car park and Olefines Administration building located closest to the CPWE. A commercial and light industrial development is located further to the west of the Olefines Administration building (outside the BIP).

Section 2 Background

The nearest residential areas are located to the east of the BIP along Denison Street with recreational areas located immediately to the east of the CPWE. The areas surrounding the CPWE and the BIP also include schools, retirement villages, shopping centres, golf courses, commercial/industrial premises, Penrhyn Estuary and Botany Bay.

2.4 Environmental Setting

2.4.1 Topography and Drainage

The BIP is located in an area of former sand dunes and coastal swamps within the Botany Basin. The elevation of the site drops from around 20 m above sea level on the eastern side of the site to less than 5 m above sea level on the western side. An extensive low-lying area (less than 5 m above sea level) which was formerly swampy occurs to the west of the site. Natural drainage on the site is towards two man-made drains, Springvale and Floodvale Drains, which drain the low-lying area southwards to Botany Bay. The drains enter Botany Bay via Penrhyn Estuary, which was formed by the reclamation of the Port Botany Container Terminal area.

Springvale and Floodvale Drains were excavated in the late nineteenth century, prior to the establishment of the ICI Australia Operations Pty Ltd (ICI)[2] Botany site in the early 1940s, to assist in the drainage of Veterans Swamp and surrounding areas. The urban stormwater systems follow the natural fall of the land and discharge mainly into Springvale and Floodvale Drains or the drains to the east of the site.

The CPWE is situated on an elevated area formed from coastal sand dunes, it is elevated above surrounding areas due to the encapsulation. The car park is relatively flat. The upper section of the CPWE is approximately 2 m higher then the surrounding land to the south, east and north. The CPWE is approximately 6 m above the land to the west.

On the BIP itself, uncontaminated stormwater discharges into Springvale Drain. Treated trade waste effluent is discharged into the Sydney Water sewer system.

2.4.2 Geology

In general, the site is underlain by the Botany Sands, a sequence of predominantly unconsolidated to semi-consolidated permeable sands. These are interspersed with lenses and layers of peat, peaty sands, silts and clay that become more common in the lower part of the sequence. The sand sequence which is 30 to 60 m thick is underlain by sandstone rock (Hawkesbury Sandstone) which has a very low permeability compared to the sand deposits. Extensive peat layers occur at or close to the surface in adjoining low lying areas. Peat layers have also been noted in many shallow foundation boreholes drilled over wide areas of the site.

2.4.3 Hydrogeology

In general, the Botany Sands contain and transmit groundwater and are referred to as the Botany aquifer. The main groundwater recharge areas are in the higher sandy country to the north and east of the site. Water table gradients indicate that groundwater flows predominantly in a westerly and south-westerly direction towards Botany Bay, however the inferred shallow groundwater flow direction in the vicinity of the CPWE is in a south-easterly direction. The variation in groundwater flow in the vicinity of the CPWE is likely to be due to groundwater extraction from Qenos Pty Ltd (Qenos) production bores located in the general vicinity of the CPWE. Based on information provided by Orica, these production bores have been active since the 1980s and are still active, producing between 1 and 2 ML/day in total.

[2] ICI Australia Operations now known as Orica Australia Pty Ltd

Section 2 Background

The Botany aquifer is one of the few high yielding, low salinity coastal aquifers in NSW. It was one of the early sources of water for Sydney and it remains an important source of industrial water in the Botany area. A number of groundwater bores have been identified within the residential areas located to the east and west of the site. Not many of the bores within the residential area have been registered, however anecdotal information indicates that residential bores are reasonably common in the area assessed along the western margin of the 'Northern Plumes' of contaminated groundwater. A Groundwater Extraction Exclusion Area has been declared by the Department of Natural Resources (DNR) that encompasses the BIP (including the CPWE), Hensley Athletics Field and residential/commercial areas south of Fraser Avenue, east of the CPWE.

The groundwater in the vicinity of the BIP has been heavily impacted as a result of past industrial practices, the contamination in the groundwater was first identified in a survey conducted for Orica Australia in 1990. Orica is taking a multi-action approach to contain the contaminated groundwater, prevent it from entering Botany Bay and clean up the contamination. The groundwater remediation is not part of the CPWE remediation project.

Section 3 Issue Identification/ Data Evaluation

3.1 General

A number of studies have been undertaken on and surrounding the BIP, as well as studies specific to the CPWE site. The following sections present a review of available data for environmental media relevant to the CPWE site. Data is currently available for soil, groundwater, and vapour (soil gas emissions). The prime objective of the review of available data is to identify chemicals that warrant derivation of risk-based remediation concentrations, i.e. COPCs.

COPCs are those chemicals, which are known or suspected to be present at concentrations high enough to warrant assessment of risks to human health or the environment, or to pose a nuisance (e.g. odours). The prime objective of identifying COPCs is to focus the derivation of risk-based concentrations (RBCs) on those that have the potential to significantly contribute to risks to human health.

3.2 Identification of Chemicals of Potential Concern

Exposure pathways associated with the presence of contamination in soil (refer to **Section 5**) include incidental ingestion and dermal contact as well as inhalation of vapours and particulate matter. The available data indicates contamination is limited to the stored waste and the immediate area of the CPWE site. In identifying COPCs the following should be noted:

- Only the analytical results from the material located within the encapsulation were considered, data that represented samples of the CPWE liner (Hypalon) and field trial samples were not included in the assessment. Some of the results from these samples represented the highest concentrations identified however material such as the Hypalon forms < 1% of the total mass of material to be treated, the bulk of the contamination is in the soil. Therefore the exclusion of these samples provides a representation of the material that is to be treated.
- Chemicals have been selected as a COPC only if the concentration is above the limit of reporting (LOR). It should be noted that the laboratory LOR was raised for a number of compounds for a number of samples in the halogenated aliphatic compound group. However, as these compounds are volatile and based on the proposed remediation technology for the site, it is not considered likely that they will be present (if at all) in the remediated material. If these compounds are detected above laboratory LORs then they may require further consideration if they exceed the adopted guideline investigation levels.
- COPCs for the CPWE project were identified based on soil gas data by URS in HCB Waste Management Plan Human Health Risk Assessment (URS 2002). These COPCs have been further refined following the collection of additional data. A discussion on the refinement of the COPCs is provided below.

3.2.1 Selection of COPCs

COPCs from Soil Gas Data

COPCs were identified by URS in the HCB Waste Management Plan Human Health Risk Assessment (URS 2002) in the analysis of potential emissions to air that may be of concern during remedial options. The COPCs were identified based on soil gas concentrations, as well as detected semi-volatile compounds. The maximum concentrations of chemicals reported on the site from the soil gas sampling data were screened against adopted screening levels relevant to short-term exposures[3] no calculations were performed on the soil gas data to account for dilution or dispersion following release, treatment or

[3] Adopted short-term screening levels were derived from Region IX Preliminary Remediation Goals (PRGs) for ambient air. The PRGs are presented for long-term exposures and hence a modifying factor was applied to adjust the level to those relevant to short-term exposures (refer to report for further detail, URS 2002a).

Section 3 Issue Identification/ Data Evaluation

discharge. While not recognised in Australia, the screening levels adopted (PRGs) provide values for a wide range of chemicals for the purpose of identifying COPCs. The NSW Environment Protection Agency (EPA, now the DEC) approved the use of these guidelines for screening purposes during completion of the HCB Waste Management Plan Human Health Risk Assessment (URS 2002a and b). These COPCs are relevant to the assessment of potential risks associated with remediation of the CPWE (as presented within the EA), however they do not address all chemicals that may be present in the soil materials to be remediated and may be present at concentrations above appropriate values for the BIP after remediation.

Review of Additional Soil Data

To ensure that all relevant COPCs are considered in the derivation of risk-based soil concentrations, a review of the soil sampling data in the Waste Material Characterisation Report (Woodward-Clyde 1998) and Car Park Waste Encapsulation and Denison Street Stockpile – Further Characterisation Final Report (URS 2007) was undertaken to identify additional COPCs. The data reported by URS (2007) are considered to be a more appropriate basis for characterisation of the materials present within the encapsulation due to the greater intensity of sampling as part of the characterisation process for the treatment technology. Previous reports included only limited sampling as part of the HCB Waste Management Plan (Woodward-Clyde 1998).

Where appropriate (i.e. where more than five positive results have been reported) 95% Upper Confidence Levels (UCLs) of the average concentrations have been calculated from the entire URS (2007) data set. The 95% UCL values have been compared to the NEPM F (commercial/industrial) and USEPA Region 9 and Region 3 Industrial land use PRGs to identify COPCs for the purposes of calculating risk-based soil criteria.

The presence of high concentrations of contaminants in some samples collected by URS (2007) has resulted in higher laboratory LORs and in some cases these are greater than the screening guidelines. However, these chemicals have not been identified as COPCs for calculation of RBCs. The calculation of risk-based soil concentrations may be warranted for these chemicals should subsequent investigations achieve lower LORs and the concentrations are found above the screening guidelines (i.e. determined to be a potential site COPC). Alternatively the screening guidelines could be used as the site criteria.

The following chemicals were detected in the Woodward-Clyde (1998) study but were not detected above the LOR in the larger study (URS 2007):

- chloroform;
- chloromethane;
- cis-1,4 dichloro-2-butene;
- 1,1 dichloroethane;
- 1,1 dichloroethene;
- trans 1,2 dichloroethene; and
- vinyl chloride.

Two chemicals were detected in the Woodward-Clyde (1998) study and in the URS (2007) study, however the 95% UCL concentrations reported were below the screening guidelines. These chemicals are:

- hexachloroethane; and
- pentachlorobenzene.

It should also be noted that some chemicals analysed in the Woodward-Clyde (1998) investigation were not included in the URS (2007) investigation namely:

- methylene chloride (dichloromethane); and

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- tetrachlorobutadiene.

In the absence of additional data these chemicals have been identified as COPCs.

In the URS 2007 investigation, the analysis of OCS is considered to be an estimate[4] and hence 95% UCL concentrations have not been determined.

It is noted that the screening levels are relevant for commercial/industrial use of the site, consistent with the current and expected land use. As no sensitive environmental receptors have been identified on the site, and, consistent with the industrial land use, the selection of the screening levels has focused on the protection of human health. Only chemicals reported above the LOR in at least one sample have been reviewed. Samples from all depths within the encapsulation have been considered as potential being located on the surface following remediation.

Detailed in **Table 3.1** are the calculated 95% UCL and maximum concentrations and the guideline values. Any chemical which reported a 95% UCL concentration above the adopted guideline or reported a maximum concentration which was above 250% of the adopted guideline was considered a COPC. The chemicals which have been identified as COPCs and hence warrant calculation of a soil RBC are highlighted in bold in the table. The sample locations where the maximum concentrations were detected are listed in **Table 3.1** (refer to **Figure 3** for locations).

[4] OCS is not a standard analyte included in the NATA accredited method used by the laboratory, hence quantification is regarded as an estimate with reduced accuracy.

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Table 3-1 95% UCL Concentrations for CPWE mg/kg

Chemical	95% UCL Concentration	Maximum Concentration (location)	Adopted Guideline Value
Arsenic	6.3	18 (SB10_1.0-1.5)	500[1]
Cadmium	1.1	3 (SB03_1.0-1.3)	100[1]
Chromium	26.1	138 (SB05 3.5-4.1)	60000[1]
Copper	19.8	106 (AH02 4.0-4.3)	5000[1]
Lead	24.4	59 (SB03 1.0-1.3)	1500[1]
Nickel	20.9	130 (SB05 3.5-4.1)	3000[1]
Zinc	118.7	764 (SB05 3.5-4.1)	35000[1]
Mercury	2.9	14.7 (SB02 3.0-3.6)	75[1]
cis-1,2-Dichloroethene	**28.8[5]**	**24.4 (SB09 4.2-4.3)**	**15[2]**
1,2-Dichloroethane (EDC)	**27.8[5]**	**1.2 (SB09 4.2-4.3)**	**0.6[2]**
Trichloroethene (TCE)	**38.1**	**176 (SB02 3.0-3.6)**	**0.11[2]**
1,1,2-Trichloroethane	**48**	**313 (SB02 3.0-3.6)**	**1.6[2]**
Tetrachloroethene	**251.7**	**1010 (SB02 3.0-3.6)**	**1.3[2]**
1,2-Dibromo-3-chloropropane	**27.8[5]**	**2.4 (SB07 1.2-1.6)**	**2[2]**
Hexachlorobutadiene[4](HCBD)	**1848.5** 1520.4	**24,300 (CPWE liner)[6]** 35,100 (CPWE liner)[6]	**22[2]**
1,2,4-Trichlorobenzene[4]	28.5 9.3	68.3 (SB02 3.6-4.1) 68.3 (SB02 3.0-3.6)	220[2]
2-Methylnaphthalene	0.52	0.8 (SB02 3.0-3.6)	15[3]
2-Chloronaphthalene	0.83	6.2 (SB02 3.6-4.1)	290[3]
Fluorene	0.61	2.4 (SB02 3.6-4.1)	26000[2]
Phenanthrene	0.53	1 (SB02 3.0-3.6)	100[1]
N-Nitrosomorpholine	0.52	0.8 (SB01 2.0-2.6)	NA
Acetophenone	0.76	4.9 (SB02 3.6-4.1)	370[3]
Bis(2-chloroethyl) ether	0.83	6.1 (SB02 3.6-4.1)	2.6[3]
1,3-Dichlorobenzene	0.9	*7.4* SB02 (3.6-4.1)	600[2]
1,4-Dichlorobenzene	1.3	*14.9* SB02 (3.6-4.1)	7.9[2]
1,2-Dichlorobenzene	1.03	9.7 (SB02 3.6-4.1)	600[2]
Hexachloroethane	19.2	71.1 (SB01 2.0-2.6)	120[2]
Hexachlorocyclopentadiene	2.6	4.5 (SB01 3.0-3.4)	3700[2]
Pentachlorobenzene	14.9	130 (SB02 3.6-4.1)	490[2]
Hexachlorobenzene	**107**	**896 (CPWE liner)[6]**	1.1[2]
1,2,4,5-tetrachlorobenzene	9.6	82.1 (SB02_3.6-4.1)	180[2]
PCBs (total)	10.4	20 (SB03 3.5-4.1)	50[1]

1- NEPM F Commercial/Industrial, phenanthrene has been compared to the "total PAH" value (i.e. 100 mg/kg) which is conservative.
2- USEPA Region 9 Preliminary Remediation Goals (PRGs) October 2004.
3- USEPA Region 3 RBC Table October 2006.
4- Hexachlorobutadiene and 1,2,4-trichlorobenzene are included in two analytical groups namely halogenated aliphatic compounds and chlorinated hydrocarbons both sets of data are provided above.
5- LOR has been assigned when the results reported were below LOR, hence some 95% UCL concentrations may be greater than the maximum concentration reported.
6- Liner samples were not used in the derivation of the 95 % UCL.

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The following chemicals in Table 3.2 have been identified as COPCs:

Table 3-2 Identified COPCs for Derivation of RBC

• Octachlorostyrene (OCS); • Hexachlorobenzene (HCB); • Hexachlorobuta-1,2-diene; • Pentachlorobutadiene (and related isomers); • Methylene chloride (commonly known as dichloromethane); and • Tetrachlorobutadiene (and related isomers)	Identified as COPCs from Woodward-Clyde Waste Characterisation Report (1998) and URS (2002a)
• 1,2-Dichloroethane (EDC); • cis-1,2-Dichloroethene; • Hexachlorobuta-1,3-diene (commonly known as hexachlorobutadiene, HCBD); • Tetrachloroethene; • 1,1,2-Trichloroethane; • Trichloroethene (TCE); and • 1,2-Dibromo-3-chloropropane.	Identified as COPCs from soil sampling (URS 2007)

3.3 Suitability of Data

Assessments of accuracy and precision using quality control data collected in the field and at the laboratory were performed on the data at the time of reporting it is considered to be suitable for use in the derivation of risk based remediation concentrations. No further evaluation of accuracy and precision has been undertaken by URS in completion of this report.

Section 4 Toxicity Assessment

4.1 General

The objective of the toxicity assessment is to identify toxicity values for the COPC that can be used to quantify potential risks to human health associated with calculated intake. Toxicity can be defined as *"the quality or degree of being poisonous or harmful to plant, animal or human life"* (NEPM 1999).

The steps involved in this process include the following:

- Obtain relevant qualitative and quantitative toxicity information on the COPCs relevant to the significant exposure pathways being assessed (namely oral, dermal, or inhalation); and
- Identify the appropriate toxicity values for assessing both threshold effects and non-threshold carcinogenic effects.

The toxicity assessment distinguishes between those chemicals that can be assessed on a non-threshold and a threshold basis as described below.

Non-Threshold

Non-threshold toxicity values assume that any amount of exposure to the chemical has the potential to result in an increased risk. These chemicals are typically carcinogens with their toxicity values referred to as cancer risk slope factors. The World Health Organisation (WHO) assigns slope factors to chemicals identified as genotoxic carcinogens with other carcinogens evaluated generally identified as exhibiting a threshold relationship (refer below). A slope factor is an upper bound estimate of the probability of a response occurring following the intake of a chemical over a lifetime via a specific exposure pathway (such as ingestion or inhalation). Therefore, the higher the slope factor, the higher the risk which may be associated with a given exposure.

Threshold

This relationship assumes that there is a level of exposure below which there is no (or no appreciable) risk of an adverse health effect. This is in contrast to the non-threshold relationship where there is an increased risk associated with any exposure. The WHO identifies threshold chemicals as those which are not suspected of exhibiting carcinogenic effects (non-carcinogens) or those which exhibit non-genotoxic carcinogenicity. Toxicity factors for these chemicals are referred to as an acceptable daily intake (ADI, by the WHO) or reference dose (RfD, by the USEPA) for oral exposures (in units of milligram (mg) per kilogram (kg) body weight per day) and a tolerable concentration (TC, by WHO) or reference concentration (RfC, by USEPA) for inhalation exposures (in units of mg per cubic metre of air). The lower the ADI, RfD, TC, or RfC, the more toxic the chemical and the lower the concentration above which there exists a potential for an adverse health effect.

4.2 Identification of Toxicity Values

The identification of toxicity values undertaken in this risk assessment has followed guidance provided by enHealth (2002) and NEPC (1999) enHealth (2002) provides a list of toxicological data sources. These are classified as Level 1, 2 or 3 data, with Level 1 sources recommended. In order of preference the Level 1 sources are:

1) NHMRC documents and documents from other joint Commonwealth, State and Territory organisations.
2) ADI List from the Therapeutic Goods Administration.
3) WHO documents.
4) enHealth Council documents.
5) NEHF documents.

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6) International Agency for Research on Cancer (IARC) monographs.

7) WHO/Food and Agriculture Organisation (FAO) Joint Meeting on Pesticide Residues (JMPR) monographs.

8) National Industrial Chemicals Notification and Assessment Scheme (NICNAS) Priority Existing Chemical (PEC) reports.

9) US Agency for Toxic Substances and Disease Registry (ATSDR) documents.

10) National Toxicology Program (NTP) carcinogenicity appraisals.

11) Organisation for Economic Co-operation and Development (OECD) Standard Information Data Sets (SIDS) and SID Initial Assessment Reports (SIAR).

12) USEPA Reference Doses.

Level 2 sources include peer-reviewed journals and industry publications and reference to Level 2 sources is considered warranted where Level 1 sources do not provide applicable criteria. Level 3 sources are other sources not covered in Levels 1 or 2. The use of Level 3 sources requires justification that no other data are available and that the appraisal presented meets the required level of conservatism as required. Level 3 sources have not been considered in the toxicity reviews presented in this report.

4.3 Toxicity Reviews

Toxicity profiles have been prepared for the COPCs identified in **Section 3**. These profiles provide a review of potential health effects associated with exposure and identification of relevant toxicity values for the quantification of risk associated with oral, dermal, and inhalation exposures. The toxicity profiles for the COPCs identified in this assessment are presented in **Appendix A** of this report. The profiles provide an overview of current consensus of the toxicity of the chemicals with an aim of identifying toxicity values that reflect the enHealth (2002) guidance. It is not the purpose of the reviews to derive alternate toxicity values.

Table 4.1 presents a summary of the toxicity values identified for use in this assessment. The toxicological data presented are considered to be appropriate for the assessment of risks to human health associated with potential exposure to the COPCs. It is accepted that toxicological data has many uncertainties (as outlined in Section 9 of this report). However, the approaches adopted by the different regulatory bodies in determining the relevant toxicological values are considered to be conservative and likely to overestimate the risks.

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Table 4-1 Summary of Toxicity for COPCs

Chemical	Non-Cancer Toxicity Endpoint	Animal Carcinogen and Mechanism	Genotoxic	Oral Slope Factor $(mg/kg/day)^{-1}$	Oral TDI (mg/kg/day)	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Inhalation TC (or equivalent) (mg/m^3)	TWA [6] (mg/m^3)	Potential for background intake
tetrachloroethene (PCE)	Liver, kidney, CNS	Yes, P, C, MG	No	T	0.014[3]	T	0.2[2]	335	Yes (34%)
trichloroethene (TCE)	CNS, liver	Yes, P, C, MG	Equivocal	T	0.00146[1]	$4.3x10^{-7}$ [2]	NT	54	Yes, low
cis-1,2-dichloroethene	Liver	Insufficient data	Potential	T	0.01 [4]*	T	O	793	Negligible
1,1,2-trichloroethane	Liver, immune	Yes, C	No	T	0.004[4]	T	O	55	Negligible
1,2-dichloroethane (EDC)	Liver	Yes, M,G	Yes	0.012[1],[3]	NT	$(0.5 \text{ to } 2.8)x10^{-6}$ [2] $2.8x10^{-6}$ proposed	NT	40	Negligible
dichloromethane (DCM)	Liver, kidney, CNS	Yes, M	No	T	0.0012[3]	T	1[5]	174	Yes (20%)
hexachlorobenzene (HCB)	Liver	Yes, NG	No	T	0.00016[1]	T	O	0.002[7]	Negligible
hexachlorobutadiene (HCBD)	Kidney	Yes, M,C	Equivocal	T	0.0002[3]	T	O	0.21	Negligible
1,2-hexachlorobutadiene	Insufficient data available to assess – use data available for HCBD as surrogate								
pentachlorobutadiene	Insufficient data available to assess – use data available for HCBD as surrogate								
tetrachlorobutadiene	Insufficient data available to assess – use data available for HCBD as surrogate								
octachlorostyrene (OCS)	Liver and kidney	Insufficient data	No	T	0.00031 [8]	T	O	Adopt data for HCB as surrogate	Negligible
1,2-dibromo-3-chloropropane	Liver	Yes	Potential	0.035[1]	NT	$0.69x10^{-4}$ [4]**	NT	0.0097[7]	Negligible

Notes:

(1) Derived from WHO Drinking Water Guidelines (1993, 1996, 1998, 2004 and rolling revisions)
(1*) Derived from WHO guidelines using inhalation data
(2) Derived from WHO Air Quality Guidelines (2000, 2000b or current CICAD reviews (relevant for chloroform and PCE). Where a range is presented, the most conservative value (higher unit risk and lower ADI) has been adopted.
(2*) Noted to be a conservative approach as threshold may be appropriate
(3) Derived from ANZECC/NHMRC Australian Drinking Water Guidelines (2004)
(4) Derived by USEPA (IRIS evaluations)
(4)* Derived from HEAST – peer reviewed US source
(4)** Currently withdrawn from IRIS and under review.
(5) Derived by ATSDR (chronic exposures)
(6) Occupational data available from National Occupational Health and Safety Commission (NOHSC) except where noted, TWA values based on 8-hour average
(7) Occupational data available from ACGIH, TWA value based on 8-hour average
(8) Data available from Health Canada

O Inhalation exposure evaluated using oral data as no relevant chronic inhalation data available
I Oral exposures evaluated on the basis of inhalation data as no chronic oral data are available
T Threshold approach adopted, hence no oral slope factor or inhalation unit risk considered relevant
NT Non-threshold approach adopted
NA Not available
NG= Non-genotoxic C = Cytotoxic P = Peroxisome proliferation
G = Genotoxic M = metabolite mediated with questionable relevance to humans
MG = species specific α2-microglobulin mechanism
TEQ = Toxicity Equivalence
TDI = Tolerable daily intake
TWA = Time Weighted Average
TC = Tolerable Concentration

Section 5 Exposure Assessment

5.1 General

This section identifies the human populations (receptors) who may be exposed to the COPCs, outlines the mechanisms (pathways) by which these populations may be exposed, and provides a quantitative estimate of exposure and chemical intake.

The exposure assessment is undertaken to be representative of a particular population and does not calculate the exposure for a given individual. Populations are grouped so as to reflect common activities undertaken by that group (such as intrusive workers or office workers) or by the location of the population in relation to the contaminant distribution. For this reason, it is important that the exposure assessment be undertaken in such a way that the most sensitive individuals within the potentially exposed population are adequately protected. The exposure assessment has been structured in the following way:

- Identification of the group that may be exposed to the COPCs;
- Identification of the activities by which exposure may take place for each group;
- Identification of parameters that define activity (such as time spent indoors) and physiological exposure parameters (such as body weight and inhalation rate); and
- Identification of the chemical concentration at the point of exposure. This may include the identification and use of models to estimate chemical concentrations for receptors and exposure pathways that cannot be measured directly.

5.2 Key Pathways and Receptors

Receptor populations are similar groups of people who work in areas affected by the contamination and who may be exposed to the COPCs in the workplace.

An exposure pathway describes a unique mechanism by which an individual within the population may be exposed to chemicals or physical agents at or originating from a source. Each exposure pathway includes:

- a source or release from a source;
- a transport/exposure medium or exposure route; and
- an exposure point.

If any one of these mechanisms is missing (such as transport mechanism or exposure point), then the pathway is considered to be incomplete. An exposure pathway can be considered to be insignificant if the potential for a receptor or population to be exposed to the COPCs is considered to be low. This may be due to a number of factors, which may include dilution during the transport from the source to the point of exposure or limited time for exposure.

Based on the land use of the BIP, including the CPWE site, and the nature and extent of impacts identified in soils, the following exposure pathways are considered to be complete and to warrant further assessment for the key receptor groups identified.

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Table 5-1 Summary of Key Exposure Pathways

Receptor	Exposure Pathway	Activity
Adult workers on site	Inhalation of volatile COPCs derived from contamination in soils (indoors and outdoors) Ingestion of COPCs identified in soils Dermal contact of COPCs identified in soils	Work on the site within buildings placed over the remediated soils. Work on the site outdoors in the vicinity of the remediated soils.

Exposures by visitors would be lower than long-term workers due to the short duration spent on site. Hence, quantification of risks to visitors is not proposed to be undertaken.

In addition it is noted that there is the potential for workers involved in intrusive activities on the site to be exposed to COPCs in soils such as during construction works. As the soils are to remain within the BIP, intrusive works will be managed under existing site management plans that include health and specific safety requirements and works permits. Hence the potential for exposure by intrusive workers within the BIP have not been considered further in the derivation of risk based soil concentrations.

5.3 Quantification of Chemical Intake

5.3.1 Methodology

When calculating chemical intake or exposure, the risk assessment process focuses on exposure occurring over a prolonged period, that is, chronic exposure that occurs over years and possibly a lifetime. Whilst an activity may occur infrequently (i.e. several days a year), it may occur over a long period (i.e. every year for years or decades), and, therefore, have the potential to increase long term, or chronic, intake of the chemical. Activities that occur rarely only have limited potential to make a significant contribution to long-term chemical intake.

The calculation of daily chemical intake requires the estimation of relevant exposure parameters that describe physical and behavioural variables relevant to the exposure evaluated, as well as chemical concentrations (in this case derived soil concentrations) that are considered relevant to the exposure evaluated).

The assessment presented has addressed potential worst-case exposure to COPCs. Exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario, estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative, or overestimate, of total exposure and, therefore, health risk. This approach follows guidance from enHealth (2002) and NEPC (1999), supplemented by USEPA guidance (USEPA 1989).

The following presents the general methodology adopted for the calculation of chemical intake via inhalation, ingestion, and dermal exposure pathways. Most equations are derived from USEPA (1989).

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Intakes via Inhalation

The following equation is used to calculate intake of chemicals via all inhalation pathways:

$$Daily\ Chemical\ Intake_V = C_a \bullet \frac{InhR \bullet ET \bullet FI \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

where:

C_a = Concentration of chemical in air (as relevant for each pathway assessed) (mg/m^3)

InhR = Inhalation rate (dependent on age and activity) (m^3/hr)

ET = Exposure time (dependent on activity) (hr/day)

FI = Fraction inhaled from contaminated source assumed to be 1 or 100% unless noted otherwise (unitless)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (dependent on age) (kg)

AT = Averaging time for threshold and non-threshold exposures (days)

Intakes via Ingestion

The following equation is used to calculate intake of chemicals via the incidental ingestion of soils pathways:

$$Daily\ Chemical\ Intake_{Is} = C_s \bullet \frac{IRs \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

where:

C_s = Concentration of chemical in soil (as relevant for each pathway assessed) (mg/kg)

IRs = Ingestion rate of soil (dependent on age and activity) (mg/day)

FI = Fraction of daily ingestion that is derived from contamination source assumed to be 1 or 100% unless noted otherwise (unitless)

B = Bioavailability or absorption of chemical via ingestion assumed to be 1 or 100% unless noted otherwise (unitless)

CF = Conversion factor of 1x10^{-6} to convert mg to kg

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (dependent on age) (kg)

AT = Averaging time for threshold and non-threshold exposures (days)

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Intakes via Dermal Exposures

The assessment of dermal exposures involved quantification of intakes from soil that may be encountered by workers on site during regular activities by workers undertaking maintenance activities. The approach adopted for the quantification of dermal contact with soils is consistent with the approach presented in the Orica Botany Consolidated Human Health Risk Assessment (URS 2005) which is detailed below:

Mechanisms of Dermal Absorption

Passive diffusion, as governed by Fick's First Law, is considered to be the main process whereby chemicals enter and permeate through the skin. The human skin is the largest organ of the body, and it consists of a thin (approximately 100 micrometers (µm)) epidermal layer superimposed on a thick dermal layer (approximately 300-400 µm). The epidermis consists of four layers, with the outermost layer being the stratum corneum (SC) (approximately 10-40 µm), which overlays the strata lucidum, granulosum, and germinativum. The SC layer is composed of flat highly keratinised squamous cells that are nonviable and are thought to maintain the barrier properties of the skin. If the SC layer is removed by tape stripping, for example, the permeability of the skin to chemicals increases dramatically.

Factors that have an effect on the dermal absorption of chemicals through the skin include:

- Skin hydration, with several studies indicating that skin hydration may increase skin permeability;
- Thickness of the SC, with anatomic regions with higher absorption expected in areas unprotected by thick SC layers;
- Lipophilicity of chemical. The SC layer tends to be a lipid-rich milieu, and, hence, provides a barrier to hydrophilic compounds but permits the entry of lipophilic compounds; and
- Physiologic factors, including genetic-related sensitivity (e.g. tendency to sunburn) and individual differences (e.g. age, the presence of skin disease, skin abrasions).

Models that are used to estimate dermal absorption of chemicals present in soils are simplifications of the more complex dermal absorption processes.

Dermal Contact with Soil

Dermal absorption of chemicals from soil depends on the area of contact; duration of contact; bond between chemical and the soil; and the ability of the chemical to penetrate the skin.

USEPA Approach

The USEPA (1989 and 2004) define a simple approach to the evaluation of dermal absorption associated with soil contact. This is presented in the following equation:

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$$\text{Daily Chemical Intake} = C_s \bullet \frac{SAs \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

where:

C_s = Concentration in soil (mg/kg)

SAs = Surface area of body exposed to soil per day (cm^2/day)

AF = Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil properties and area of body (mg/cm^2 per event)

ABSd = Dermal absorption fraction (unitless – refer to discussion below)

CF = Conversion factor of $1x10^{-6}$ to convert mg to kg

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (dependent on age) (kg)

AT = Averaging time for threshold and non-threshold exposures (days)

Dermal Absorption Fraction (ABSd): The approach undertaken by the USEPA utilises a dermal absorption fraction typically derived from experimental studies on different chemicals. On the basis of the studies undertaken and a number of simplifications, ABSd values have been recommended for a range of 10 chemicals and default values for other semi-volatile chemicals. No default is defined (in USEPA 2004) for volatile organic chemicals (VOCs) or inorganic chemicals. It is considered that, with regards to soil exposures, VOCs would volatilise from soil on skin and should be accounted for in the assessment of inhalation exposures. For inorganics, the speciation is very important to dermal absorption, and, hence, no generic default values have been determined.

More commonly used values for the assessment of dermal exposure to organics and inorganics utilise defaults for ABSd for organics of 0.01 and inorganics of 0.001, as presented on RAIS (Risk Assessment Information System, originally derived from USEPA 1992), along with the few chemical-specific values that are available.

The value of ABSd has no consideration of exposure time. Experimental studies used to define ABSd values are associated with dermal application over 24 hours (i.e. the event is considered to be a 24 hour day by default). Due to the lack of information about the rate and relationship of absorption of chemicals through the skin over shorter exposure periods, the USEPA methodology does not recommend adjusting the ABSd to account for exposures over times less than 24 hours; rather, it recommends adjusting exposure frequency and exposure duration to reflect site conditions. This approach is utilised to evaluate dermal intake per exposure event (commonly adopted as a day) and is considered to be conservative in the assessment of exposure events that are less than 24 hours in duration or multiple short-term exposure events, where absorption would be "double-counted".

Further Review of Dermal Absorption

In reviewing the approach to the assessment of dermal exposure presented in source documents "The Health Risk Assessment and Management of Contaminated Sites" (CSMS, 1991, 1993, 1996, 1998 and enHealth 2002) that are referenced in enHealth (2002), it is noted that the approach suggested by Hawley (1985) has been adopted. The approach is similar to the USEPA approach presented above, with some differences with respect to the evaluation of absorption.

Hawley (1985) provides a review of dermal uptake from soils for organic chemicals, based on studies of a number of compounds by humans, rats, rabbits and pigs. The absorption rates obtained for application of

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a pure compound (or in acetone solvent) were determined to be 11% for an adult over 24 hours. For a 12 hour contact time, the dermal absorption rate was taken to half, or 6% (as rounded up from half of 11%), of the applied dose. For children a higher rate was assumed to account for more permeable skin of a young child. For children the absorption rate was taken to be twice that of the adult, or 12% of the compound on the skin over 12 hours.

Absorption of contaminants in soils or dust was discussed by Hawley to be limited by the physical-chemical binding of the contaminant to the matrix. On this basis, Hawley also applied use of a factor to account for the matrix effect of absorption from soils (or relevant matrix) by comparison to the absorption study data that used the pure compound or solvent solution. The value used by Hawley (for TCDD and other organic compounds where no data is available) was 15%.

This approach is also adopted in the assessment of dermal intake of organic chemicals presented in the Dutch sediment exposure model SEDISOIL (1996) and the soil exposure model CSOIL (2001). These models express the dermal absorption of organics presented by Hawley as an absorption rate per hour. Hence, for children the absorption rate is 0.01 or 1% per hour and for adults the absorption rate is 0.005 or 0.5% per hour.

This approach was generally utilised by Fitzgerald D.J (CSMS 1991) in the setting of a response level for benzo(a)pyrene, where intake via skin absorption for a 2 ½ and 6 year old child utilises the dermal absorption value over 24 hours. For an adult the intake via skin absorption considers exposure to soils over 12 hours and adjusts the intake using a linear relationship for absorption. While many other response levels (in various papers in CSMS) have been established following this approach, they are typically set for a 2 ½ year old child where dermal absorption associated with soils over 24 hours is considered to be relevant. Other references where dermal absorption over shorter exposure periods than 24 hours (using the linear approach) are presented in the following:

- Di Marco P.N. and Buckett K.J in CSMS 1996 in “Derivation of Health Investigation Levels for Beryllium and Beryllium Compounds”
- Di Marco P.N. in CSMS 1993 in “The Assessment and Management of Organochlorine Termiticides” where exposures over 24 hours (children), 8 and 10 hours (adults).
- Di Marco P.N. and Buckett K.J in CSMS 1993 in “Derivation of A Health Investigation Level for PCBs”

It is proposed that the methodology presented by Hawley (1985), SEDISOIL (1996) and CSOIL (2001) be adopted for the assessment of dermal exposures to chemicals identified in soils at the CPWE site. The methodology is considered appropriate for the range of COPCs identified at the site. On this basis, dermal intake from exposure to soil will be determined using the following equation:

Section 5 Exposure Assessment

$$Daily\ Chemical\ Intake_{Ds} = C_s \bullet \frac{SAs \bullet AF \bullet Abs \bullet ET \bullet ME \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

where:

C_s = Concentration in soil (mg/kg)

SAs = Surface area of body exposed (cm^2)

AF = Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil/sediment properties and area of body (mg/cm^2 per event)

Abs = Dermal absorption rate (per hour) – based on chemicals specific information or use of default values of 0.01 per hour for children and 0.005 per hour for adults (as above)

ET = Exposure time to soil (hours/day)

ME = Matrix effect (unitless) – dependent on the nature of dermal data available, by default 0.15 or 15% assumed (discussed above)

CF = Conversion factor of $1x10^{-6}$ to convert mg to kg

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (dependent on age) (kg)

AT = Averaging time for threshold and non-threshold exposures (days)

5.3.2 Exposure Parameters

Exposure parameters that are considered representative of RME have been selected for the receptor groups evaluated. Where available, exposure data has been obtained from Australian sources (CSMS, 1991, 1993, 1996 and 1998, ANZECC 1992, NEPM 1999 and enHealth 2002 and 2003). **Appendix D** presents the calculation of daily intake, including the exposure parameters selected and used in the assessment. The following presents a summary of the key assumptions:

Section 5 Exposure Assessment

Table 5-2 Exposure Parameters Adopted Worker On Site

Receptor Population	Exposure Pathways	Chemical Concentrations	Exposure Parameters
			Parameters relevant for all pathways Body weight of 70 kg Exposure for 12 hours per day (i.e., long work shifts) for 240 days/year (5 days per week for 48 weeks) for 30 years
Worker On site (Adult) →	Inhalation of COPCs present in soils →	Vapour phase and particulate concentrations modelled from soil concentrations →	Inhalation of 1.17 m^3 air per hour indoors (10 hours) and 2.2 m^3 air per hour outdoors (2 hours).
↘	Ingestion and dermal contact with COPCs in soils →	Derived soil concentrations assuming all remediated soils could be placed at the surface. →	Ingestion of 25 mg of soil per day by adults. Once ingested it is assumed that 100% is absorbed into the body. When outdoors it is assumed that the hands get dirty each day (1120 cm^2 of skin). Once dirty it is assumed that 0.51 mg of soil adheres to each cm^2 of skin. Assume an adult will wash at the end of each day resulting in up to 12 hours of the day dirty.

Section 6 Risk Characterisation

6.1 General

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure assessment and toxicity assessment to provide a quantitative assessment of non-threshold carcinogenic risk and threshold health effects. Risks have been characterised as part of the process involved in the development of risk-based soil concentrations such that the derived soil concentrations result in a level of risk equal to the target levels. The following is a description of the approach adopted in the quantification of risk and the general acceptance criteria considered relevant for the assessment of potential risks to all of the COPCs identified.

6.2 Approach and Assessment Criteria

6.2.1 Risk for Non-Threshold Effects

The potential for unacceptable non-threshold carcinogenic risks associated with exposure to COPCs has been evaluated using USEPA methodology.

Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. The numerical estimate of excess lifetime cancer risk is calculated as follows:

Non-Threshold Risk = Daily Chemical Intake • Cancer Slope Factor

The total non-threshold carcinogenic risk is the sum of the risk for each chemical for each pathway.

Deciding whether the calculated non-threshold carcinogenic risk is of concern or not requires identification of an acceptable risk level. The calculation of a non-threshold carcinogenic risk implies that any exposure to these chemicals may result in an increased risk or probability of contracting cancer over a lifetime. The non-threshold carcinogenic risk value is expressed as a probability such as 1 in 10,000 ($1x10^{-4}$) or 1 in 1,000,000 ($1x10^{-6}$). At the simplest level these probability values can be converted to population risks as follows:

- An incremental lifetime non-threshold carcinogenic (or cancer) risk of $1x10^{-6}$, means that in a population of 1 million people which has been exposed to the chemical for their lifetime one additional cancer is predicted over and above the background incidence of cancer in that population (1 million people). For the same population a cancer risk of $1x10^{-4}$ implies that 100 additional cancers are predicted over and above the background incidence (for 1 million people).

These values are extremely low when compared to the background incidence of cancer in our society. The background incidence is in the order of 1 in 4 to 1 in 3 (Fitzgerald, CSMS 1993). This means that for a population of 1,000,000 around 250,000 individuals are expected to contract cancer over a lifetime. An additional $1x10^{-6}$ risk predicts 1 additional individual may develop cancer.

Specific Australian guidance related to the significance of cancer risk estimates is not currently available. Current USEPA policy states that: *"Where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, ... action is generally not warranted unless there are adverse environmental impacts"* (USEPA 1991). If risks are found to be greater than the 10^{-4} probability, then the USEPA recommends that a preliminary remediation goal of 10^{-6} cancer risk be developed as the point of departure (ibid).

Section 6 Risk Characterisation

A review of the origins of the 10^{-6} cancer risk number has been undertaken by Kelly (1991) and a review of the development of an Australian approach to the assessment of carcinogenic contaminants has been prepared for discussion by Fitzgerald (1993). Both these reviews indicate that the 10^{-6} was suggested by the United States Food and Drug Authority (USFDA) in 1961, as representing the *de minimis* legal risk. That is, the level of risk that can be identified, in a legal sense, as being representative of negligible or trivial risk. As the more recent USEPA policy (quoted above) indicates, the application of cancer risks has seen the acceptance of higher risk values i.e. 10^{-4} or 1 in 10,000 in the assessment of contaminated sites.

The application of cancer risk values in Australia and elsewhere is generally consistent with the USEPA policy. That is, the 10^{-6} risk value is commonly identified as the point of departure from negligible risk and the 10^{-4} risk value is commonly adopted as indicative of unacceptable risks. The 10^{-6} risk value is sometimes used as the basis for defining ambient standards applicable to wide scale population exposure. For example, the NHMRC and the Agricultural and Resources Management Council of Australia and New Zealand (NHMRC/ARMCANZ 2004) have used the 10^{-6} value for the derivation of the Australian drinking water guidelines for genotoxic carcinogens. The WHO, on the other hand, has used the 10^{-5} risk as the basis for the derivation of the WHO drinking water guidelines (WHO 2004) and the Dutch use the 10^{-4} lifetime cancer risk as the basis for the derivation of Human Intervention Values for soil and groundwater for genotoxic carcinogens.

URS understand that a goal of 10^{-5} is generally accepted on a range of sites by a number of EPA-accredited auditors (Contaminated Land Auditor) as indicating conditions that might warrant specific management or remedial action. The acceptance of the goal is site dependent. URS is not aware of any stated policy by the DEC.

Based on the above discussion, URS considers that the following guidance with respect to incremental lifetime cancer risks is representative of current practice in NSW:

- Calculated incremental risks below 1 x 10^{-6} would be considered to be effectively zero;
- Calculated incremental risks between 1 x 10^{-6} and 1 x 10^{-5} would be considered acceptable; and
- Calculated risks greater than 1x 10^{-4} would be considered to warrant some form of action or management to reduce the risk.

Where risks fall between 1 x 10^{-5} and 1 x 10^{-4}, then this may warrant further evaluation of the risks to determine whether action is required to reduce the risks.

Adopted Target Non-Threshold Carcinogenic Risk

For the purpose of deriving risk-based soil concentrations, URS has adopted a Target Risk value of 1 x 10^{-5} relevant to the sum of excess lifetime cancer risk over all COPCs and exposure pathways. To assist in deriving the risk-based soil concentrations, an individual Target Risk level of 1 x 10^{-6} has been adopted to ensure that exposure to multiple chemicals is addressed (resulting in a total risk from all chemicals that is less than the target of 1 x 10^{-5}).

6.2.2 Hazard Index for Threshold Effects

The potential for adverse threshold effects, resulting from exposure to a COPC, has been evaluated by comparing an exposure level, expressed as a daily chemical intake, with the adjusted ADI or equivalent threshold value (tolerable daily intake (TDI), reference dose (RfD)). The resulting ratio is referred to by the USEPA as the hazard quotient (USEPA 1989) and is derived in the following manner:

$$Hazard\ Quotient = \frac{(Daily\ Chemical\ Intake)}{(ADI) - (Background\ Intake)}$$

Section 6 Risk Characterisation

The evaluation of risk associated with threshold chemicals involves a comparison of the total daily intake with the adjusted ADI. The adjusted ADI is that which has been adjusted for background intake (refer to Toxicity Summaries in **Appendix A** for details on background intakes) from all other sources so that the hazard quotient calculated compares the chemical intake derived for the specific exposure scenario with the ADI allowable from sources other than background. If the total daily chemical intake exceeds the adjusted ADI, TDI or RfD (i.e. if the hazard quotient exceeds one), then this would indicate potentially unacceptable chemical intakes. The hazard quotient does not represent a statistical probability of an effect occurring.

To assess the overall potential for adverse health effects posed by simultaneous exposure to multiple chemicals, the hazard quotients for each chemical and exposure pathway are summed. The resulting sum is referred to by the USEPA as the hazard index (HI) (USEPA 1989). The HI approach assumes that multiple sub-threshold exposures to several chemicals could result in a cumulative adverse health effect, and exposures are summed over all intake routes.

If the HI is less than one, cumulative exposure to the site chemicals is judged unlikely to result in an adverse effect. If the index is greater than one, a more detailed and critical evaluation of the risks (including consideration of specific target organs affected and mechanisms of toxic action of the chemicals of concern) would be required to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

Adopted Target Threshold Hazard Index

For the purpose of deriving risk-based soil concentrations, URS has adopted a Target HI value of 1 relevant to the sum of HI over all COPCs and exposure pathways. To assist in deriving the risk-based soil concentrations, an individual Target HI of 0.1 has been adopted to ensure that the potential for exposure to multiple chemicals is addressed.

Section 7 Risk-Based Soil Concentrations

7.1 Approach

Soil RBCs have been calculated using the toxicity and exposure assumptions detailed in **Sections 4** and **5**. Values have been calculated for each COPC irrespective of whether a particular COPC contributes significantly to the health risk. Target risks (refer to **Section 6**) have been set assuming a combined exposure to all of the COPCs identified as well as on an individual chemical basis (i.e. assumes risks are additive). This approach is a way of addressing uncertainty with respect to exposure to the chemical mixture, as characterised by the samples collected as part of the waste material characterisation, and is conservative (i.e. results in a low RBC).

The RBCs have been derived using the following approach:

- Human health RBCs for outdoor areas have considered potential exposures associated with COPCs in soils that may be present (or placed) in an open area where no buildings are to be located in the future. The RBCs have been derived to be protective of direct contact (including dermal and ingestion) with the soils and the inhalation of vapour and particulates in the outdoor air. The RBCs have also been derived taking into consideration the depth to the remediated material. Clean top fill may be placed above the remediated material therefore values have been determined for three different depths of clean fill - 1, 2 and 3 m, and for when the material is at the surface.
- Human health RBCs for indoor areas have considered potential exposures associated with COPCs in soils that may be present (or placed) in an area where a building will be constructed over the top of the soils. The RBCs have been derived to be protective of the inhalation of vapours that may migrate into and accumulate within the building as direct contact with the soil is not relevant.
- For these scenarios, the human health RBC for each individual COPC has been derived by adjusting the concentration in soil such that the total risk from all exposure pathways is equal to the individual risk target adopted for individual chemicals.

In following this process it is noted that the derived RBCs are specific to the CPWE site and are not generic concentrations that could be applied to other sites. Furthermore, the RBCs for outdoor areas are not applicable to areas under buildings and vice versa.

It should be noted that during the CPWE remediation project, the proposed RBCs can be adjusted to account for additional COPCs should they be identified as well as a different distribution of individual risk targets (such as a higher RBC for a chemical found to be more persistent in the remediation process and a lower value for another chemical found to be more successfully treated or not present at the concentrations expected on the basis of the existing data).

The RBCs may be used for the following purposes:

- Reviewing soil data from the areas adjacent to the encapsulation within the CPWE boundary. If all COPCs in samples are below the RBCs, then further assessment of the health risks would not be warranted.
- As conservative remediation criteria. The RBCs may be used for identifying on site reuse options for the treated material.

7.2 RBCs

7.2.1 Human Health RBC Values

Tables 7.1 and **7.2** summarise the derived human health RBCs for the key COPCs identified at the CPWE site that are expected to contribute to the total risk. The table lists the total risk values for all COPCs. Calculations undertaken to establish the human health RBCs are presented in **Appendix D**.

Section 7 Risk-Based Soil Concentrations

Table 7-1 Human Health RBCs for COPCs in Soil Indoors

Constituent	RBC Surface (mg/kg)	RBC 1 m (mg/kg)	RBC 2 m (mg/kg)	RBC 3 m (mg/kg)
1,2-dichloroethane (EDC)	3.2	3.3	3.4	3.5
cis-1,2-dichloroethene	6.5	6.8	6.8	6.8
hexachlorobenzene (HCB)[6]	55	5000	5000	5000
hexachlorobuta-1,2-diene[1]	4.5	5	5	5
hexachlorobuta-1,3-diene (HCBD)	4.5	5	5	5
methylene chloride (DCM)	130	135	135	135
octachlorostyrene (OCS)	110	5000	5000	5000
pentachlorobutadiene[1]	4.2	4.5	4.5	4.5
tetrachlorobutadiene[1]	4.2	4.5	4.5	4.5
tetrachloroethene (PCE)	16	16	16	16
1,1,2-trichloroethane	15	16	16	16
trichloroethene (TCE)	1	1	1	1.1
1,2-dibromo-3-chloropropane	9.5	9.5	10	10

1. There is no available toxicity data for hexachlorobuta-1,2-diene, pentachlorobutadiene and tetrachlorobutadiene, and toxicity data for hexachloro-1,3-diene (hexachlorobutadiene) has been adopted.
2. Vapour migration is based on diffusion and advection with advection (not sensitive to depth) dominating.
3. The calculated risk values for these COPCs are limited by the chemicals' theoretical saturated vapour concentration and fall well below the adopted target risk level of either 1x10 (non-threshold) and 0.1 for threshold. In theory this means that for these chemicals risk based soil concentrations could be a concentration of 100% of the soil. Arbitrary values therefore have been set as follows: surface concentrations have adopted outdoor calculated RBC and at depth a nominal value of 5,000 mg/kg.
4. The assessment of indoor concentrations is limited to the inhalation indoors pathway only. Direct contact and ingestion have not been considered.
5. The target risk for threshold chemicals has been set at 0.1, while more than 10 risk based soil concentrations have been derived and in theory the HI total of 1 could be exceeded if all the chemicals are present at the risk based soil concentration level. This is considered unlikely and in the event that all species are present at the concentrations presented here then the risk based soil concentrations may require revision.
6. The RBC may not be applicable should material be classed as waste in which case Scheduled Waste criteria will be applicable to this chemical (refer to Section 7.2.2).

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Table 7-2 Human Health RBCs for COPCs in Soil Outdoors

Constituent	RBC Surface (mg/kg)	RBC 1 m (mg/kg)	RBC 2 m (mg/kg)	RBC 3 m (mg/kg)
1,2-dichloroethane (EDC)	52	110	230	330
cis-1,2-dichloroethene	110	230	450	660
hexachlorobenzene (HCB) [6]	55	5000[4]	5000[4]	5000[4]
hexachlorobuta-1,2-diene[1]	38	5000[4]	5000[4]	5000[4]
hexachlorobuta-1,3-diene (HCBD)	38	5000[4]	5000[4]	5000[4]
methylene chloride (DCM)	280	5000[4]	5000[4]	5000[4]
octachlorostyrene (OCS)	110	5000[4]	5000[4]	5000[4]
pentachlorobutadiene[1]	35	5000[4]	5000[4]	5000[4]
tetrachlorobutadiene[1]	35	5000[4]	5000[4]	5000[4]
tetrachloroethene (PCE)	1500	5000[4]	5000[4]	5000[4]
1,1,2-trichloroethane	210	500	1000	5000[4]
trichloroethene (TCE)	17	36	70	100
1,2-dibromo-3-chloropropane	21	300	600	5000[4]

1. There is no available toxicity data for hexachlorobuta-1,2-diene, pentachlorobutadiene and tetrachlorobutadiene, and toxicity data for hexachloro-1,3-diene (hexachlorobutadiene) has been adopted.
2. Vapour migration is based on diffusion and advection with diffusion (sensitive to depth) dominating.
3. The assessment of surface RBC outdoors has considered inhalation, dermal and ingestion pathways. Only inhalation has been considered relevant at depth.
4. The calculated risk values for these COPCs are limited by the chemicals' theoretical saturated vapour concentration and fall well below the adopted target risk level of either $1x10^{-6}$ (non-threshold) and 0.1 for threshold. In theory this means that for these chemicals risk based soil concentrations could be a concentration of 100% of the soil, therefore a nominal RBC of 5,000 mg/kg has been set.
5. The target risk for threshold chemicals has been set at 0.1, while more than 10 risk-based soil concentrations have been derived and in theory the HI total of 1 could be exceeded if all the chemicals are present at the risk based soil concentration level. This is considered unlikely and in the event that all species are present at the concentrations presented here then the risk based soil concentrations may require revision.
6. The RBC may not be applicable should material be classed as waste in which case Scheduled Waste criteria will be applicable to this chemical (refer to Section 7.2.2)

7.2.2 Consideration of Director General's EARs

The Director General's EARs as outlined in **Section 1.2** provide levels that are required to be achieved in treated soil from the proposed remediation project. The use of the RBCs must take into account the EARs outlined in **Section 1.2** or other criteria as agreed or defined within the RAP (HLA 2007).

Section 7 Risk-Based Soil Concentrations

More specifically, the following can be noted:

- The chemicals identified in the Director General's EARs are dioxins (as dioxins, furans and dioxin-like PCBs as a WHO TEQ), PCBs and Scheduled Chemical Wastes (SCW), constituents that include HCB.
- Dioxins furans, dioxin-like PCBs and PCBs have not been identified as COPCs based on available data. Therefore, RBCs have not been derived for these chemicals.
- With respect to SCW, the only SCW constituent identified as a COPC in the CPWE is HCB (Chemical Control Order (CCO) in Relation to SCW, 2004). The lowest RBC derived for HCB is 55 mg/kg, which is above the level stated in the Director General's EARs.
- The determination of best practice concentrations for treated material is discussed in the EA and RAP (HLA 2007).

7.3 Use of RBCs and Validation

This section outlines the use of the RBCs and other soil criteria in the validation of the CPWE, as outlined in the RAP (HLA 2007). The RBCs have been derived to be used for the following purposes:

- Remediated material to be validated for reuse at the CPWE or other areas on-site (Orica owned property or other areas within the BIP as agreed); and/or
- Criteria for validation of the CPWE excavation.

To use the RBCs for either of these purposes, the correct RBCs are required to be selected, i.e. Soil Indoors or Soil Outdoors and depth at which the material is placed or identified.

The RBCs have been developed according to the end use of the material, such as beneath a building or in areas where no building is to be placed, and consideration has been given to the amount of clean top fill that may be placed above the validated materials. If the incorrect RBC is applied for the end use, the target risk levels may be exceeded for on site users. Prior to the commencement of excavation the appropriate RBCs will need to be agreed on with the Contaminated Land Auditor.

URS recommends that additional vapour sampling be carried out to ensure that the site is suitable for future commercial/industrial landuse (see **Section 7.3.3** and **Appendix E**).

The RBCs are site specific and do not apply for off-site disposal. If the treated material is to be disposed off-site the material will need to comply as a minimum with the DEC (2004) *Environmental Guidelines: Assessment, Classification & Management of Liquid and Non-Liquid Wastes* and if relevant the CCO in Relation to SCW (2004) and the CCO for PCBs (1997).

7.3.1 Chemicals to be Investigated

The RBCs have been developed following detailed review of sampling undertaken within the CPWE of the waste materials and vapour phase concentrations (refer to **Section 3** for details). As the material to be treated is a waste product of variable nature there is the potential for some of the material to contain elevated concentrations of chemicals for which RBCs have not been derived. Therefore a process has been developed to identify these chemicals and select appropriate guideline values to evaluate the use of the material on site in respect to human health.

Once the waste material has been treated in accordance with the RAP (HLA 2007) the material to be reused on site will require validation. In addition the extent of excavation will also require validation. Samples for analytical testing will be collected at a frequency to be agreed on with the Contaminated Land Auditor and specified in the RAP (HLA 2007). The range of chemicals to be analysed should also be agreed on with the Contaminated Land Auditor and specified in the RAP (HLA 2007), however URS anticipates that the chemicals to be investigated would include, as a minimum:

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- any chemical included in the Director General's EARs or as agreed or defined in the RAP (HLA 2007) (for excavated material only); and
- any chemical for which RBCs have been derived. It is important to note that the RAP should also include an approach to address uncertainty in selecting the RBC list of chemicals. This may include an expanded analyte list or ensuring that the laboratory checks all chromatograms from analysis to determine if other chemicals are present at elevated concentrations (and subsequent reanalysis).

For the validation of the material surrounding the encapsulation (the landscaping material) URS anticipates that the chemicals to be investigated would include the above and any chemical identified above the LOR in the following reports (or as agreed with the Contaminated Land Auditor);

- HCB Waste Management Plan Waste Material Characterisation (Car Park Waste). Prepared by AGC Woodward-Clyde Pty Ltd (February 1998).
- Final Report Car Park Waste Encapsulation and Denison Street Stockpile - Further Characterisation. Prepared by URS Australia Pty Ltd (March 2007).

Care needs to be taken to ensure that appropriate LORs are achieved to enable comparison with appropriate guidelines.

7.3.2 How the RBC and Other Guidelines Are to be Applied

A hierarchy of guidelines and a decision making process has been derived to assist in the application of the RBCs and other guidelines. The guidelines should be utilised in the following order:

- The Director General's EARs or as agreed or defined in the RAP (HLA 2007) for excavated material only;
- The derived RBCs relevant for the end use and depth; and
- If concentrations above the LOR are identified for chemicals that are not included in the above criteria then screening level criteria (as agreed to by Contaminated Land Auditor) should be used to assess whether it is a COPC and if so, an additional RBC will need to be derived.

Flow diagrams are provided below in **Figures 4** and **5** to assist with the application of the various guidelines with respect to the reuse of validated materials on-site and the validation of the excavation.

Care needs to be taken to ensure that the correct RBC is selected based on the intended use of the soil material such as the use outdoors, beneath a building and placement of top soil above the validated soils (extent of excavation) and/or remediated material. In addition care needs to be taken to ensure that the remediated material is used for the purpose that was identified in validation. It should be noted that if the material is not used for the purpose identified during validation then risks to human health may exceed the target levels. For example, if material is validated using the RBC derived for use outdoors and at a depth of 3 m and is then placed on the surface above which a building is constructed, then the risks to human health for workers inside the building may exceed the target levels. It is therefore essential that a strategy to identify and track the end use of material be identified in the RAP. If the end use of the material is not known then the most sensitive guideline should be applied, that is the Soil Indoor Surface RBC.

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Figure 4 Flow Diagram for the Reuse of Treated Material On-site.

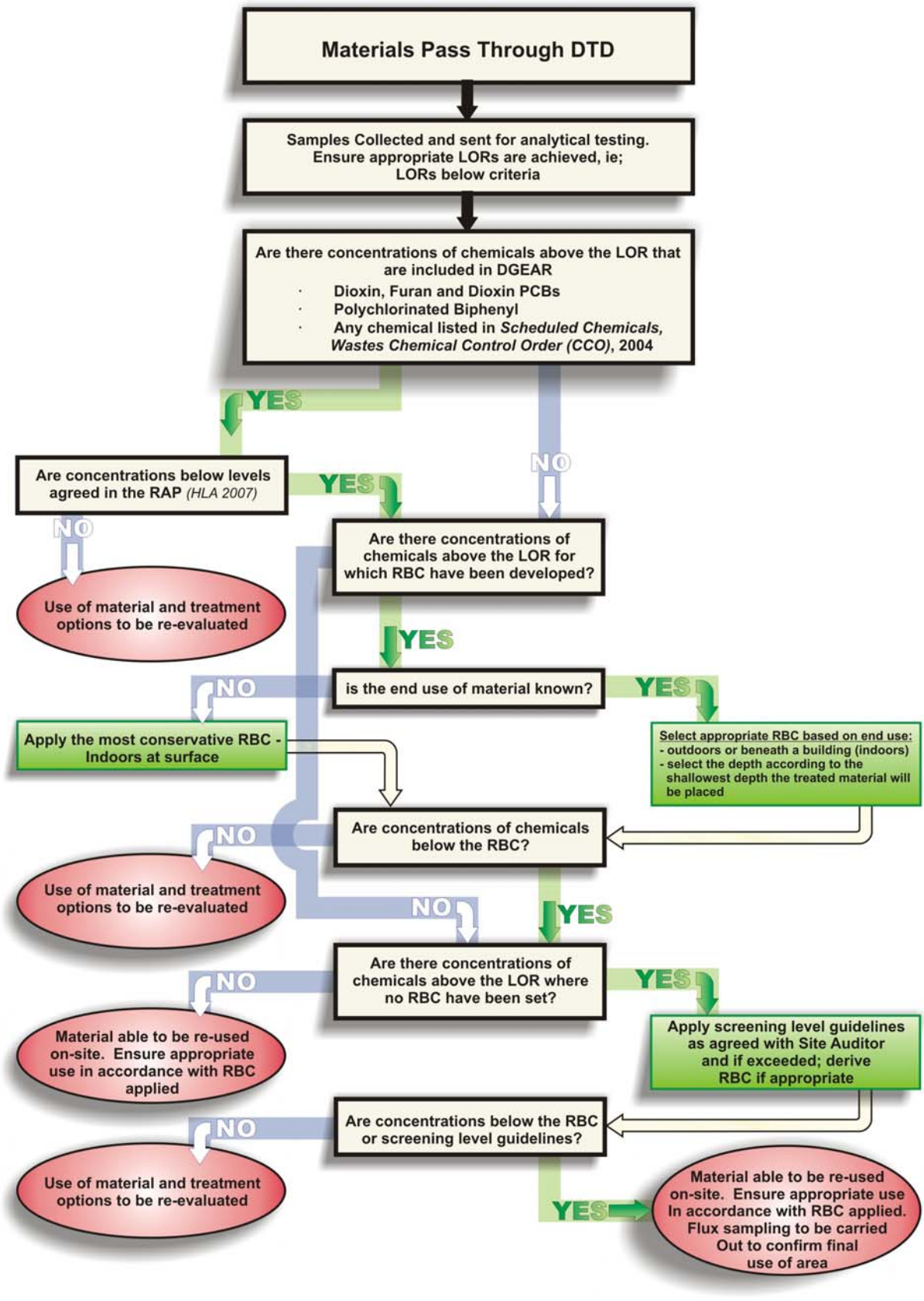

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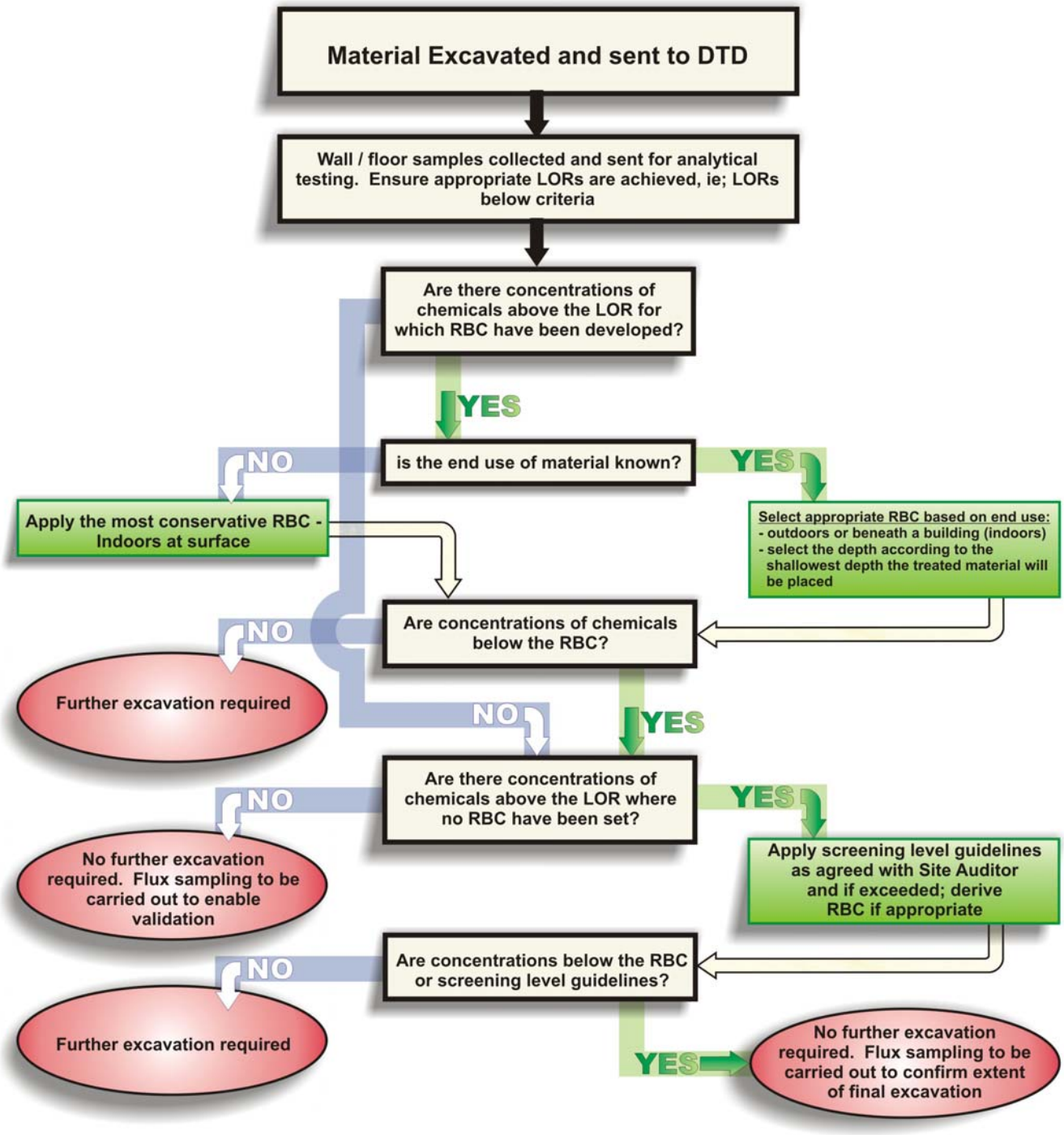
Figure 5 Flow Diagram for the Validation of the CPWE Excavation.



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7.3.3 Additional Recommendations

As the only pathway for exposure associated with the existing CPWE has been identified as volatile emissions from the surface of the ground, it is considered important that the final assessment of the base and reinstated area includes a review of vapour emissions.

Hence, in addition to the routine sampling and analysis of soil, URS recommends that additional samples be collected to confirm that the CPWE site is suitable for ongoing commercial/industrial landuse with or without management measures, e.g. a Site Management Plan. The additional sampling would include flux emission sampling using Summa Canisters and sorbent tubes in the following locations:

- the excavation bases in the CPWE prior to reinstatement to confirm that volatile COPCs (which includes all volatile and semi volatile compounds identified as COPCs) have been adequately removed (and are not of significance from the underlying groundwater) such that the land is suitable for ongoing commercial/industrial landuse (with or without management measures); and
- on the treated material after reinstatement in the CPWE area to confirm that volatile COPCs have been adequately removed (and are not of significance from the underlying groundwater) and are acceptable for ongoing commercial/industrial landuse (with or without management measures).

The methodology for flux emission sampling is provided in **Appendix E**, included in this appendix is a proposed sampling frequency and analytical list however these will need to be agreed with the Contaminated Land Auditor prior to the commencement of sampling.

Section 8 Conclusions

A human health risk assessment model has been used to assist in the derivation of re-use criteria for material removed from the CPWE encapsulation during remediation. The approach used has involved the assessment of potentially complete exposure pathways relevant to outdoor and indoor workers.

This assessment assumes working lifetime exposure (30 years) for an adult worker to soils after re-use. These exposure duration assumptions are likely to result in a conservative estimate of human health risks. As risks have been calculated on the basis of prolonged exposure to the contaminants at the site, risks for individuals who visit the site infrequently will be lower and can be assumed to be negligible.

There is the potential for workers involved in intrusive activities on the site to be exposed to COPCs in soils such as during construction works. As the soils are to remain within the BIP, intrusive works will be managed under existing site management plans that include health and specific safety requirements and works permits. Hence the potential for exposure by intrusive workers within the BIP have not been considered in this assessment.

Section 9 Uncertainties and Sensitivity Assessment

9.1 Uncertainties

9.1.1 General

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Sampling and analysis;
- Receptor exposure assessment; and
- Toxicological assessment.

The risk assessment process following both ANZECC/NHMRC and USEPA guidance documents provides a systematic means for organising, analysing and presenting information on the nature and magnitude of risks to public health posed by chemical exposures. Despite the advanced state of the current risk assessment methodology, uncertainties and limitations are inherent in the risk assessment process. This section discusses the uncertainties and limitations associated with this risk assessment.

9.1.2 Sampling and Analysis

The data collected for soil and air from the Orica CPWE site has been based on the knowledge of the site geological conditions and former site activities. The analytes have also been selected based on a knowledge of former site activities and, hence, has focussed on chemicals that were known to have been formerly used at the site. The soil data utilised in this risk assessment was collected by URS in 2007. URS has used 95% UCL concentrations and maximum concentrations for the determination of COPCs. There is potential for chemicals to be present on the site which have not been characterised due to incomplete site historic records.

9.1.3 Exposure Assessment

Risk assessments require the adoption of several assumptions in order to assess potential human exposure. This risk assessment includes assumptions about general characteristics and patterns of human exposure relevant to the BIP. The assumptions used are conservative and developed to provide an estimate of reasonable maximum exposures, rather than the actual exposures. This approach tends to overestimate the risks. The assessment has been completed using upper bound concentrations reported in soil. This assumption may therefore overestimate the potential for exposure to the COPCs.

9.1.4 Toxicological Assessment

In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals.

This may introduce two types of uncertainties into the risk assessment, as follows:

1) Those related to extrapolating from one species to another; and
2) Those related to extrapolating from the high exposure doses, usually used in experimental animal studies, to the lower doses usually estimated for human exposure situations.

The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals, although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response. There may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to

extrapolate results of short term or subchronic animal studies to humans exposed over a lifetime has inherent uncertainty.

In order to adjust for these uncertainties, ADIs and RfDs incorporate safety factors that may vary from 10 to 1000. The USEPA assumes that humans are as sensitive to carcinogens as the most sensitive animal species. This policy decision, while designed to minimise the potential for underestimating risk, introduces the potential to overestimate carcinogenic risk. Conversely, it also does not allow for the possibility that humans may be more sensitive than the most sensitive animal species. The model used by the USEPA to determine slope factors is a linearised multistage model, which provides a conservative estimate of cancer risk at low doses and is likely to overestimate the actual slope factor. It is assumed in this approach that a genotoxic mechanism applies; however, most carcinogens do not actually cause cancer by this mechanism. The result is that the use of slope factors has the general effect of overestimating the incremental cancer risks.

The approach for evaluating risks to mixtures of chemicals assumes dose additivity and does not account for potential synergism, antagonism, or differences in target organ specificity and mechanism of action. In general, the additive approach has the effect of overestimating the risks. This is because chemicals that have no additive effects are included together as well as chemicals that may have additive effects.

9.1.5 Sensitivity Assessment

The assessment of risk involves the use of models to estimate exposure and, in some cases, exposure point concentrations. These models require a number of input variables, some of which may be site-specific and others may be derived from other sources of information.

Table 9.1 presents a list of the major input variables used in the risk assessment presented for the calculations undertaken at the site. The table presents the range of practical values for each variable, the value used in the risk assessment, the relative model sensitivity, and the uncertainty associated with the variable. This is required to evaluate the sensitivity of the many assumptions used in the quantification of risk.

Table 9-1 Input Variables, Sensitivity and Uncertainty

Input Variable	Practical Range of Values	Value Used in Risk Assessment	Effect on Risk if Variable Increased	Relative Model Sensitivity	Relative Uncertainty
Vapour Migration Model Used to Estimate Air Concentrations					
Soil dry bulk density	Dependent on soil type, may range from 1.3 to 2.0 g/m^3 for sand	1.6 g/cm^3 for sandy gravel fill 1.8 g/cm^3 for ash/sand/peat	Decrease	Moderate	Moderate (no field data available)
Moisture Content	Dependent on soil type, reported by HLA to vary from 8.5% to 30%	10% (or 0.10) adopted as representative for site	Decrease	Moderate to High	Low
Organic carbon fraction	Dependent on soil type, reported by HLA to vary from 0.5% to 5.9%	1% (0.01) assumed for sandy gravel fill 0.3% (0.003) assumed for ash/sand	Decrease	Moderate to high	Moderate as value likely to be variable, conservative value adopted
Enclosed air exchange rate	0.18 to 4 per hour	2 per hour for commercial buildings	Decrease	Moderate	Low (conservative value used)
Fraction of cracks in walls and foundations	0.001 to 1	0.001 as conservative value for concrete slab (accounts for cracks and joins)	Increase	Moderate	Moderate

Section 9 Uncertainties and Sensitivity Assessment

Input Variable	Practical Range of Values	Value Used in Risk Assessment	Effect on Risk if Variable Increased	Relative Model Sensitivity	Relative Uncertainty
Soil	Range of values reported on and off site	Maximum and 95% UCL concentrations adopted	Increase	Moderate	Low (conservative, maximum values used in QRA)
Risk Assessment					
Inhalation rate, ingestion rate, exposure time, dermal contact parameters.	Variable, depending on age and activity	Reasonable maximum values selected	Increase	Low	Low
Body weight	Variable depending on individual	70 kg for adults	Decrease	Low	Low

While a number of parameters used within the risk assessment have a moderate degree of uncertainty associated with them and the modelling is sensitive to changes in these parameters, values used to define these parameters have been selected to be conservative. This has resulted in the calculation of risk, which is expected to be conservative, and an overestimation of actual risk.

Section 10 Limitations

URS Australia Pty Ltd (URS) has prepared this report for the use of Orica Australia Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 25 July 2006 (WCIE 4304).

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between August 2006 and June 2007 and is based on the information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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